TITLE OF THE INVENTION

POWER SUPPLY DEVICE AND CONTROL METHOD THEREOF

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of Korean Patent Application No. 2003-1365, filed January 9, 2003, in the Korean Intellectual Property Office, the disclosure of which is incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0002] The present invention relates to a power supply device and a method of controlling the power supply device, and more particularly, to a power supply device having an inrush current protection circuit, a power factor correction (PFC) circuit and an overvoltage protection circuit and a method of controlling the inrush current protection circuit, the PFC circuit and the overvoltage protection circuit.

2. Description of the Related Art

[0003] A three-phase motor is a motor having a plurality of windings which are arranged around a rotor and which receive energy from a three phase voltage to rotate the motor. As shown in FIG. 1, a power supply device which obtains a three-phase voltage necessary for driving a motor 200 via input terminals U, V and W of the motor 200, comprises an AC power supply 100 which supplies a commercial AC power, such as for example, (AC 110/220V), a rectifier 300 which rectifies the AC power output from the AC power supply 100, a capacitor C_{DC} which smoothes a voltage rectified by the rectifier 300, an inverter 120 which inverts a DC power output from the capacitor C_{DC} to an AC power having various frequencies and outputs a three-phase voltage. The power supply device may further comprise an inrush current protection circuit 140 which prevents an inrush current into the capacitor C_{DC} during an initial supply of power, a power factor correction (PFC) circuit 150 which maintains an output voltage from the capacitor C_{DC} at a constant value, and an overvoltage protection circuit 130 which protects the capacitor C_{DC} from an overvoltage.

[0004] In the inverter 120, a pulse width modulation (PWM)part (not shown) generates a PWM control signal and a plurality of transistors are turned on/off according to a square wave signal of the PWM part. The power supply device comprises a controller (not shown) which controls the output frequency thereof so as to control a rotation speed of the motor

200 and turns on/off an output of the inverter 120 by turning on/off the transistors according to the PWM control signal.

[0005] The inrush current protection circuit 140 comprises an inrush current protection resistor Rs provided between the rectifier 300 and the capacitor C_{DC} and connected to the capacitor C_{DC}. A relay part 142 comprises first, second and third contacting points 142a, 142b and 142c. When the relay part 142 connects the first contacting point 142a with the third contacting point 142b, the inrush current protection resistor Rs connects the capacitor C_{DC} with the rectifier 300, which allows power rectified by the rectifier 300 and charged to the capacitor C_{DC} to be limited by the resistor Rs, to prevent the capacitor C_{DC} from being broken down by excessive inrush current in an initial supply of power.

[0006] The PFC circuit 150 comprises a PFC switching unit S_{PFC} such as a field effect transistor, a PFC diode D_{PFC} provided with a cathode connected to the capacitor C_{DC} and an anode connected to a node 151 of the PFC switching unit S_{PFC}, and a PFC inductor L_{PFC} provided between the node 151 and the rectifier 300. Herein, the PFC inductor L_{PFC} is disconnected from the rectifier 300 when the relay part 142 connects the first contacting point 142a with the third contacting point 142c, and connected to the rectifier 300 when the relay part 142 connects the second contacting point 142b with the third contacting point 142c. The PFC circuit 150 maintains a voltage applied across the capacitor C_{DC} at a constant value by turning on/off the PFC switching unit S_{PFC} in driving the motor 200, and improves a power factor by making an input current input to the PFC circuit 150 have a same phase as a phase of an input voltage.

[0007] The overvoltage protection circuit 130 is connected in parallel with the capacitor C_{DC}, and provided with an overvoltage protection switching unit S_{OV} connected in series with a parallel combination of an overvoltage protection diode D_{OV} and an overvoltage protection resistor R_{OV}. As to the overvoltage protection circuit 130, if the voltage applied across the capacitor C_{DC} is increased and reaches a predetermined overvoltage region due to a voltage regenerated through the inverter 120 from the motor 200 in driving the motor 200, the overvoltage protection switching unit Sov is turned On, to thereby prevent the capacitor C_{DC} from being broken down by an overvoltage.

[0008] In the conventional power supply device shown in FIG. 1, the inrush current protection circuit 140 functions until a voltage charged in the capacitor C_{DC} reaches a reference charging voltage after power is initially applied from the AC power supply 100. The

inrush current protection circuit 140 becomes unnecessary after a voltage charged in the capacitor C_{DC} reaches the reference charging voltage.

[0009] Since the PFC circuit 150 operates after the voltage applied across the capacitor C_{DC} is stabilized (i.e. sufficiently charged), operation of the PFC circuit 150 is not necessary while the inrush current protection circuit 140 operates.

[0010] Since the overvoltage protection circuit 130 operates only while the voltage applied across the capacitor C_{DC} is increased by the voltage regenerated from the motor 200, operation of the overvoltage protection circuit 130 is not necessary while the inrush current protection circuit 140 operates (i.e., in an initial charging period), or while the PFC circuit 150 operates after the voltage applied across the capacitor C_{DC} is stabilized.

[0011] Since large capacity components are used in the inrush current protection circuit 140, the overvoltage protection circuit 120 and the PFC circuit 150, a size of a product including the conventional power supply device shown in FIG. 1 is increased. Eliminating one or more of the large capacity components would result in a reduction in the product size and a decrease in manufacturing cost.

SUMMARY OF THE INVENTION

[0012] Accordingly, it is an aspect of the present invention to provide a power supply device and a control method thereof which allows a number of parts of the power supply device to be reduced, a size of the power to be reduced, a size of a product incorporating the power supply to be reduced, and manufacturing costs of the power supply device and the product to be reduced.

[0013] Additional and/or other aspects and advantages of the invention will be set forth in part in the description which follows and, in part, will be obvious form the description, or may be learned by practice of the invention.

[0014] The above and/or other aspects of the present invention are achieved by providing a power supply device having an AC power supply, a rectifier which rectifies power supplied from the AC power supply, and a capacitor which smoothes power rectified by the rectifier, comprising: a switching unit; a diode having a cathode connected to the capacitor and an anode connected to the switching unit; an inductor having a first end connectable to the rectifier and a second end connectable to a node between the switching unit and the anode of the diode; a resistor having a first end connected to the capacitor and a second end; a relay operable in a first position to connect the node between the switching unit and the

anode of the diode to the inductor, and operable in a second position to connect the node between the switching unit and the diode to the second end of the resistor; and a controller which controls the relay to be in the second position if a voltage applied across the capacitor exceeds a predetermined PFC voltage limit.

[0015] In an aspect of the present invention, the power supply device further comprises a capacitor voltage detector which detects the voltage applied across the capacitor, wherein the controller controls the relay to be in the second position if the voltage applied across the capacitor and detected by the capacitor voltage detector exceeds the predetermined PFC voltage limit.

[0016] In an aspect of the present invention, the controller turns on/off the switching unit if the voltage applied across the capacitor and detected by the capacitor voltage detector reaches a predetermined overvoltage region and the relay is in the second position.

[0017] In an aspect of the present invention, the controller controls the relay to be in the first position if the voltage applied across the capacitor and detected by the capacitor voltage detector becomes lower than the predetermined PFC voltage limit.

[0018] In an aspect of the present invention, the power supply device further comprises a second relay operable in a first position to connect the rectifier and the second end of the resistor, and operable in a second position to connect the rectifier and the first end of the inductor.

[0019] In an aspect of the invention, the controller controls the second relay to be in the first position so that power rectified by the rectifier is supplied to the capacitor through the resistor when power is initially supplied.

[0020] In an aspect of the invention, the controller controls the second relay to transfer to the second position if the voltage applied across the capacitor exceeds a predetermined reference charging voltage in a state that the second relay is in the first position.

[0021] The foregoing and/or other aspects of the present invention are also achieved by providing a method of controlling a power supply device having an AC power supply, a rectifier which rectifies power supplied from the AC power supply, a capacitor which smoothes power rectified by the rectifier, a switching unit, a diode having a cathode connected to the capacitor and an anode connected to the switching unit, and an inductor provided between the rectifier and a node between the switching device and the diode, the method comprising: providing a resistor connectable in parallel with the diode; detecting a voltage applied across the capacitor; and disconnecting the inductor and the node between

the switching unit and the diode and connecting the resistor and the node between the switching unit and the diode, if a detected voltage applied across the capacitor exceeds a predetermined PFC voltage limit.

[0022] In an aspect of the invention, the method of controlling the power supply device further comprises turning on/off the switching unit if the detected voltage applied across the capacitor reaches a predetermined overvoltage region in a state that the resistor and the node between the switching unit and the diode are connected.

[0023] In an aspect of the invention, the method of controlling the power supply device further comprises disconnecting the resistor and the node between the switching unit and the diode and connecting the inductor and the node between the switching unit and the diode, if the detected voltage applied across the capacitor becomes lower than the predetermined PFC voltage limit.

[0024] In an aspect of the invention, the method of controlling the power supply device further comprises connecting the rectifier and the resistor and disconnecting the rectifier and the inductor so that power rectified by the rectifier is supplied to the capacitor through the resistor, when power is initially supplied.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025] The above and/or other aspects and advantages of the present invention will become apparent and more readily appreciated from the following description of the embodiments, taken in conjunction with the accompany drawings of which:

FIG. 1 is a view illustrating a circuit of a conventional power supply device;

FIG. 2 is a view illustrating a state for performing an inrush current protection function in a power supply device circuit according to the present invention;

FIGS. 3A-3D are views illustrating waveforms of the power supply device circuit of the present invention in the state shown in FIG. 2;

FIG. 4 is a view illustrating a state for performing a PFC function in the power supply device circuit according to the present invention;

FIGS. 5A-5F are views illustrating waveforms of the power supply device circuit of the present invention in the state shown in FIG. 4;

FIG. 6 is a view illustrating a state for performing an overvoltage protection function in the power supply device circuit according to the present invention; and

FIGS. 7A-7E are views illustrating waveforms of the power supply device circuit of the present invention in the state shown in FIG. 6.

DESCRIPTION OF THE PREFERRED EMBODIMENT

[0026] Reference will now be made in detail to the embodiments of the present invention, examples of which are illustrated in the accompanying drawings, wherein like reference numerals refer to like elements throughout.

[0027] FIG. 2 illustrates a circuit of a power supply device circuit for a three-phase motor, according to an embodiment of the present invention. The power supply device shown in FIG. 2, comprises an AC power supply 1 which supplies a commercial AC power, such as for example, AC 110/220V; a rectifier 3 which rectifies the AC power; a capacitor 13 which smoothes power rectified by the rectifier 3; and a inverter 12 which inverts DC power outputted from the capacitor 13 to an AC power having a variable frequency and outputs the AC power as a three-phase voltage to terminals U, V and W of the motor 2.

[0028] The power supply device shown in FIG. 2 further comprises a switching unit 4; a diode 5 having a cathode connected to an end 15 of the capacitor 13 and an anode connected to the switching unit 4; an inductor 6 selectively connectable between the rectifier 3 and a node 17 between the switching unit 4 and the diode 5; a resistor 7 selectively connectable to the diode 5 in parallel; a first relay 8 having first second and third contacting points 8a, 8b and 8c, respectively, the relay 8 selectively connecting the node 17 and the inductor 6 via the first contacting point 8a and the third contacting point 8c and selectively connecting the node 17 and the resistor 7 via the second contacting point 8b and the third contacting point 8c; and a controller 11 which controls the first relay 8 to connect the second contacting point 8b and the third contacting point 8c if a voltage applied across the capacitor 13 exceeds a predetermined PFC voltage limit.

[0029] The power supply device according to the present invention may further comprise a capacitor voltage detector 10 which detects the voltage applied across the capacitor 13. The controller 11 may control the first relay 8 to connect the second contacting point 8b and the third contacting point 8c if the voltage applied across the capacitor 13 detected by the capacitor voltage detector 10 exceeds the predetermined PFC voltage limit.

[0030] The switching unit 4, the diode 5, and the inductor 6 according to the present invention, function as a PFC circuit. That is, in a state that the first relay 8 connects the first contacting point 8a and the third contacting point 8c, the switching unit 4, the diode 5, and the inductor 6 maintain the voltage applied across the capacitor 13 at a constant value by being connected to the rectifier 3 and the capacitor 13, and function as the PFC circuit to improve a power factor by controlling an input current input from the rectifier 3 to have a same phase as of an input voltage input from the rectifier 3.

[0031] The switching unit 4, such as a MOS transistor, or a Field effect transistor, is switched according to a signal input to a gate of the transistor. The controller 11 turns on/off the switching unit 4 by controlling the signal input to the gate of the switching unit 4.

[0032] The switching unit 4, the diode 5, and the resistor 7 function an overvoltage circuit. That is, while a function of the PFC circuit is performed with the first relay 8 connecting the first contacting point 8a and the third contacting point 8c, the voltage applied across the capacitor 13 may be increased by a voltage regenerated through the inverter 12 from a motor 2. If the voltage across the capacitor 13 continues to increase and exceeds the predetermined PFC voltage limit, the node 17 between the switching unit 4 and the diode 5 is cut off from the inductor 6 and the resistor 7 and the diode 5 are connected in parallel by the relay 8 connecting the second contacting point 8b and the third contacting point 8c. Herein, the controller 11 prevents the voltage across the capacitor 13 from being increased into an overvoltage region by turning on/off the switching unit 4 to reduce the voltage across the capacitor 13.

[0033] If the voltage across the capacitor 13 is decreased to the predetermined PFC voltage limit or lower, due to reduction of the voltage regenerated from the motor 2 by the overvoltage protection circuit, the controller 11 makes the first relay 8 to connect the first contacting point 8a and the third contacting point 8c. Thus, the switching unit 4, the diode 5, and the inductor 6 again function as the PFC circuit.

[0034] The power supply according to the present invention may further comprise a second relay 9 having a first contacting point 9a, a second contacting point 9b and a third contacting point 9c. The second relay 9 selectively connects the rectifier 3 and the resistor 7 via the first contacting point 9a and the third contacting point 9c, and selectively connects the rectifier 3 and the inductor 6 via the second contacting point 9b and the third contacting point 9c. The controller 11 makes the second relay 9 connect the contacting point 9a and the contacting point 9c so that power rectified from the rectifier 3 is supplied to the capacitor 13 through the resistor 7 when power is initially supplied from the AC power supply 1. Thus, the capacitor 13 is prevented from being broken down by an excessive inrush current by limiting current supplied to the capacitor 13 with the resistor 7.

[0035] The controller 11 makes the second relay 9 connect the second contacting point 9b and the third contacting point 9c if the voltage across the capacitor 13 exceeds a predetermined reference charging voltage. Thus, the rectifier 3 is connected to the capacitor 13 through the inductor 6, and the switching unit 4, the inductor 6 and the diode 5 perform the PFC function.

[0036] A process that performs functions of an inrush current protection, phase factor correction and overvoltage protection using the apparatus shown in FIG. 2 will be described will be described with reference to FIGS. 3A-3D.

[0037] When power is initially supplied from the AC power supply 1, the controller 11 makes the first relay 8 connect the first contacting point 8a and the third connecting point 8c, and makes the second relay 9 connect the first contacting point 9a and the third contacting point 9c. Referring now to FIG. 3B, an AC voltage V(L1-L2) supplied from the AC power supply 1 is rectified by the rectifier 3 to obtain a voltage VD1. The voltage VD1 is charged to the capacitor 13 through the resistor 7. That is, in a state that the first relay 8 connects the first contacting point 8a and the third contacting point 8c and the second relay 9 connects the first contacting point 9a and the third contacting point 9c, the resistor 7 performs an inrush current protection function. While performing the inrush current protection function, the voltage V_{PN} applied across the capacitor 13 is gradually increased as the capacitor 13 is charged as shown in FIG. 3B. If the voltage V_{PN} applied across the capacitor 13 exceeds a reference charging voltage V1, the controller 11 controls the second relay 9 to connect the second contacting point 9b and the third contacting point 9c. FIG.3C illustrates a waveform of a current flowing from the rectifier 3 to the resistor 7, and FIG. 3D illustrates a point of time in which the second relay 9 operates to connect the second contacting point 9b and the third contacting point 9 c.

[0038] In a state that the second relay 9 connects the second contacting point 9b and the third contacting point 9c and the first relay 8 connects the first contacting point 8a and the third contacting point 8c, the PFC function performed by the switching unit 4, the inductor 6, and the diode 5 will be described as follows, with reference to FIGS. 4 and 5A-5F.

[0039] In a state that the second relay 9 connects the contacting point 9b and the contacting point 9c, the controller 11 turns on/off the switching unit 4 so that the voltage applied V_{PN} across the capacitor 13 may be maintained constant at a value V_{DC}. That is, the controller 11 stores energy in the inductor 6 by turning on the switching unit 4, and transmits the energy stored in the inductor 6 to the capacitor 13 through the diode 5 by turning off the switching unit 4. Thus, the voltage V_{PN} applied across the capacitor 13 is maintained constant at a value V_{DC}, and an input current I_{D1} as shown in FIG. 5F input from the rectifier 3 has a same phase as a phase of an input voltage V_{D1} as shown in FIG. 5B, to thereby increase the power factor. In a state that the voltage V_{PN} applied across the capacitor 13 is maintained constant at V_{DC} by the PFC circuit, the motor 2 is driven according to a current I_{INV} as shown in FIG. 5E. FIG. 5A is a view illustrating a waveform of an AC voltage supplied

to the rectifier 3 from the AC power supply 1. FIG. 5C is a view illustrating a time when contact of the second relay 9 is switched from connecting the contacting point 9a and the contacting point 9c (A) to connecting the contacting point 9b and the contacting point 9c (B). FIG. 5D is a view illustrating a time when the PFC circuit starts to perform the power factor correction function.

[0040] While the motor 2 is driving, energy stored in the motor 2 by rotation of the motor 2 may be regenerated to the capacitor 13 through the inverter 12 under certain conditions. For example, energy stored while the motor 2 rotates regularly, is regenerated to the capacitor 13 through the inverter 12 when the motor 2 reverses a direction of rotation. Herein, energy regenerated through the inverter 12, that is, a regenerated voltage increases the voltage V_{PN} applied across the capacitor 13 above the value V_{DC}.

[0041] When the voltage applied across the capacitor 13 is increased by the regenerated voltage regenerated through the inverter 12 from the motor 2, the overvoltage protection function of the power supply device according to the present invention will be described with reference to FIGS. 6 and 7A-7E.

[0042] At first, if the voltage V_{PN} across the capacitor 13 is increased by the regenerated voltage of the motor 2 at a time t1 shown in FIG. 7B and accordingly exceeds a PFC voltage limit (V_2), the controller 11 controls the first relay 8 to connect the second contacting point 8b and the third contacting point 8c at a time t2 shown in FIG. 7C (refer to (C) of FIG. 7). The PFC voltage limit V_2 means the voltage applied across the capacitor 13 at a moment when current does not flow from the rectifier 3 to the capacitor 13 as the voltage V_{PN} is increased by the regenerated voltage.

[0043] Even when the first relay 8 is connecting the second contacting point 8b and the third contacting point 8c, the regenerated voltage from the motor 2 increases the voltage V_{PN} applied across the capacitor 13. The controller 11 turns on/off the switching unit 4 when the voltage V_{PN} applied across the capacitor 13 reaches an overvoltage region (hysteresis region, V_{H1}- V_{H2}).

[0044] That is, if the voltage V_{PN} applied across the capacitor 13 is increased and reaches an overvoltage upper limit V_{H2}, the controller 11 allows the regenerated voltage from the motor 2 through the resistor 7 to be consumed by turning on the switching unit 4 as shown in FIG. 7D. Thus, the voltage V_{PN} applied across the capacitor 13 is decreased. If the regenerated voltage from the motor 2 is consumed through the resistor 7, so that the voltage

V_{PN} applied across the capacitor 13 reaches an overvoltage lower limit V_{H1}, the controller 11 prevents the voltage V_{PN} from becoming lower than the overvoltage region (V_{H1}- V_{H2}) by turning off the switching unit 4, to maintain the voltage V_{PN} within the overvoltage region (V_{H1}- V_{H2}). Thus, the controller 11 controls consumption of the regenerated voltage from the motor 2 by turning on/off the switching unit 4.

[0045] Subsequently, if the regenerated voltage of the motor 2 is all consumed, the voltage V_{PN} applied across the capacitor 13 is not increased even though the switching unit 4 is off. Also, because the capacitor 13 is cut off from the AC power supply 1, the voltage V_{PN} applied across the capacitor 13 is decreased by power consumed to drive the motor 2. If the voltage V_{PN} applied across the capacitor 13 is decreased and becomes lower than the PFC voltage limit V_2, the controller 11 connects the capacitor 13 and the AC power supply 1 by operating the first relay 8 to connect the first contacting point 8a and the third contacting point 8c at a time t3 as shown in FIG. 7C. Herein, the capacitor 13 and the rectifier 3 are connected in the PFC circuit, and the voltage V_{PN} applied across the capacitor 13 is maintained constant by the PFC circuit.

[0046] FIG. 7A is a waveform of the input voltage (V_{L1-L2}) input from the AC power supply 1 to the rectifier 3. FIG. 7C is a view illustrating a time when the first relay 8 connects the first contacting point 8a and the third contacting point 8c (time before t2), the time t2 when the first relay 8 connects the second contacting point 8b and the third contacting point 8c and the time t3 when the first relay 8 again connects the first contacting point 8a and the third contacting point 8c during operation of the overvoltage protection circuit. FIG. 7D is a view illustrating times when the switching unit 4 is turned on/off to perform the overvoltage protection function.

[0047] In the above embodiment, the power supply device according to the present invention is illustrated by reference to a three-phase motor. However, a configuration of the inverter 12 may be changed in order to supply power to a single-phase motor or other poly-phase motors, and the power supply device according to the present invention may be applied to other devices as well as a motor.

[0048] Also, in the above embodiment, the resistor is used in common in the overvoltage protection circuit and the inrush current protection circuit. However, a separate inrush current protection resistor can be provided.

[0049] With the above configuration, in the power supply device, a number of parts may be reduced and a size and a manufacturing cost of a product may be decreased by using the

resistor 7, the switching unit 4, and the diode 5 necessary for implementing functions of the inrush current protection circuit, the PFC circuit, and the overvoltage protection circuit in common.

[0050] As described above, according to the present invention, a power supply device and a control method thereof the number of parts thereof to be reduced, and also the size of a product and manufacturing cost to be decreased.

[0051] Although a few embodiments of the present invention have been shown and described, it will be appreciated by those skilled in the art that changes may be made in these embodiments without departing from the principles and spirit of the invention, the scope of which is defined in the appended claims and their equivalents.